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The role of China's renewable powers against climate change during the 12th Five-Year and until 2020

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ABSTRACT

Climate change has become the most globally concerned environmental issue. As the world's largest carbon dioxide emitter and primary energy consumer, China has strong incentives to change its coal-dominated electricity structure. Various renewable powers such as wind and solar are suitable and necessary options for carbon emission reduction. The 12th Five-Year (2011–2015) and the mid-term until 2020 are critical periods for the development of Chinese renewable powers. In this paper individual renewable electricity sources were introduced based on their characteristics. Based on the introduction, the targets as well as their effects in the medium and long-term were presented and explained; challenges China has to face in the periods were discussed in detail, and emphasis was put on hydro, solar and wind power, which is highlighted in the plans. Also solutions against these challenges were recommended.

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1. Introduction

Climate change represents one of the greatest environmental, social and economic threats our planet has to face. Warming of climate system is evident from observation: from 1995 to 2006, eleven years rank among the twelve warmest years since 1850; increase of sea level is consistent with global warming. Worldwide average sea level rose at an average rate of 1.8 mm per year over 1961–2003 and at an average rate of about 3.1 mm per year from 1993 to 2003; observed decreases in snow and ice extent are also consistent with warming. At continental, regional and ocean basin scales, numerous long period changes in other aspects of climate such as precipitation have also been observed [1].

The reason for global warming is the presence of greenhouse gas (GHG) emissions led by carbon dioxide, which come from the unrestricted usage of fossil fuel including coal, petroleum and natural gas. International cooperation on emission reduction is necessary to mitigate climate change, and the serial conferences in Kancun as well as in Copenhagen are such attempts.

China has become the no.1 CO_2 emitter in the world, surpassing the US already in 2007 with approximately 8% more emissions [2,3]. Moreover, China is also globally the largest energy consumer, whose position is consolidated by its economic growth mode of government leading and extremely resource-extensive. In 2011, China, reaching an annual GDP growth of 9.2%, alone accounted for 71% of the global energy consumption growth [4]. Meanwhile, China is just in the middle of its industrialization, thus the still low per capita carbon dioxide emission of 5.3 t, compared with that of America, Germany and Japan of 17.5 t, 9.6 t and 9.5 t, respectively [5], makes a large increase in the total CO_2 emission inevitable in the future.

Renewable energy supplies can displace the fossil fuel combustion to reduce carbon emissions from the traditional power plants, and this is especially meaningful for China, the energy matrix of which is coal-dominated, and majority of the power plants of which are coal-fired. This has lead to many environmental problems, of which the greenhouse effect is the most serious. Globally electricity production is currently responsible for 32% of total global fossil-fuel use and 41% of energy-related carbon dioxide emissions [6]; while China is roughly in line with that—40% of total CO_2 emissions are contributed by the coal-fired power generation [7].

2. Targets of carbon dioxide emission reduction in China

As the pioneer of emerging economies, China's fossil resource consumption rose by 11.2% and 8.8% in 2010 and 2011, respectively, much faster compared with that of the worldwide growth of 5.1% and 2.5% [8].

Being the front runner of the energy expenditure as well as the carbon emission globally, China is facing ever-growing pressures from both the outside world and the internal environment.

China's high carbon dioxide emission is caused by its large population, fast industrialization and urbanization, coal-dominant energy matrix, but most importantly, the 'extensive way' of economy growth, which heavily relies on fixed capital investment and excessively consumes the valued primary resources.

It is not easy for China to transfer the traditional economic development model to a low-carbon economy. However, the financial crisis in September 2008 seemed to bring an opportunity for China. The storm caused a sharp recession worldwide, and the global primary energy consumption grew by just 1.4% in 2008, the slowest since 2001. To recover the economy, the Chinese government delivered a huge stimulus package of RMB 4000 billion (USD 586 billion) in November 2008, with emphasis on energy-extensive infrastructures instead of energy-saving industries. Thus the chance of economic transition was missing, and Chinese energy consumption growth still maintained a high level of 7.4% in 2008, accounting for nearly three-quarters of global growth [9].

However, this costly economy growth can never be sustained for long. Fortunately the Chinese government has realized this point and has pledged to push forward the transformation of the nation's economic development pattern, and to shift its focus from resource-intensive industries to high-technology ones, of which renewable energies play an important role. However, the global economic depression triggered by the European debt crisis brings a new impulse of fixed capital investment to the government. The officials must firmly stick to the strategy of sustainable and environment friendly development.

The Chinese State Council has announced a "voluntary action" to reduce the intensity of carbon dioxide emissions per unit of GDP in 2020 by 40–45 percent compared with the level of 2005. However, there is no ceiling for the total amount of emissions. The goal will be a "binding" one to be incorporated into the country's medium and long-term national social and economic development plans [10]. More funding will be invested into the research, development and industrialization of technologies for renewable energies, energy saving, and into energy efficiency improvement, clean coal development, advanced nuclear energies, and CCS (carbon capture and storage) to accelerate the construction of low-carbon industrial, construction and transportation systems.

China is now during the period of its 12th Five-Year (2011–2015) Economic and Social Development Program, in which economic, environment and clean energy are emphasized, while

Table 1
Targets in the 12th Five-Year Program and comparison with those in the 11th program.

Targets		12th Five-Year program	11th Five-Year program
Economic	GDP growth	7%	7.5% (11.2% actually)
Environment & clean energy	Non-fossil fuel	11.4% of primary energy consumption	10% (9.6% actually)
	Energy consumption per unit of GDP	16% lower	20% (19.1% actually)
	CO_2 emission per unit of GDP	17% lower	None

the GDP target was slightly slowed down (Table 1). The 12th Five-Year Plan explicitly aims at achieving a share of 11.4% for non-fossils in total energy consumption by the end of 2015, and then 15% by the year 2020. It has been decided that 17 percent reduction of carbon dioxide emissions for every GDP unit should be achieved by the end of 2015, and 40–45% by 2020, further [11,12]. To reach these goals, China's National Development and Reform Commission (NDRC) has assigned specific reduction targets to various provinces, as shown geographically in the map below (Fig. 1). In general the variable target intensities are based on individual economy developmental levels.

3. Introduction of various renewable energy power technologies

Key measures against climate change come from technical, economical and political sides, and a group of technologies including efficiency, CCS (carbon storage and storage), nuclear, biofuel, DCHP (District Combine Heating & Power), solar, wind and hydropower are expected to contribute to carbon emission saving in the future [13].

There are variable prediction scenarios for the global trend of carbon emissions, and typical prediction from IEA suggests a 70 percent increase in total by 2020, one-third of which would result from electricity generation from developing countries. To mitigate this negative impact, there would be a massive switch to renewable energy for power generation, especially to wind photovoltaic, concentrating on solar power and biomass, and it is expected that 46% of global power would come from renewables by 2050 [14,15]. Therefore, it is extremely important to keep pace with the world to make great effort to develop renewable powers, especially for those countries with rapid-growing economies, like China.

The main renewable energy sources used for electrical power generation are listed in Table 2, along with their critical characteristics [13]. Great attention is paid to hydro, wind and solar power within the group, since they have no direct emissions and their current and foreseen scales are relatively larger. Different from the renewable energies, nuclear power is not the choice for the long term since the uranium reserve is limited, and the risk of accidents results in unforeseeable associated costs, especially to the environment.

The traditional hydropower plant still accounts for the major part of the renewable sector in electricity generation. However, other new energies including wind power, solar PV, solar thermal, etc. are playing more and more important roles.

3.1. Hydropower

3.1.1. General

The hydropower plant utilizes natural elevation difference to produce electricity, and the history of several practical turbines, core of the water-powered system, can be traced back to the 1800s. However, the pumped-storage power plant has become much more popular in recent years, for it can partially compensate the grid fluctuations. Also it is highlighted in China's "Renewable Energy 12th Five-Year Plan" as well as in the program until 2020 [16].

3.1.2. Pumped-storage

Very specific geography, where two basins with a major altitude difference between them, is needed to build a pumped-storage power plant. Usually the plant has a natural inflow to the high basin [17].

This kind of plant can switch over between two different operations. When electricity is needed, the water in the higher basin is pumped through a pressure pipe to the pump turbine to produce power. The exhausted water then flows to the lower basin; in case of electricity surplus, the pump turbine functions as a pump to draw the water from the lower basin back to the higher basin. A surge tank is used in the system to mitigate the major

Fig. 1. Provincial targets of CO_2 emission reduction.

Table 2
Various renewable powers and their main characteristics.

Renewable energy source	Main characteristics
Hydro (large scale)	Well developed and widely used; water can be stored in a reservoir for flexible generation; pumped storage has two reservoirs exchanging with each other.
Hydro (small scale)	Less than 5 MW; usually service remote areas without grid connection; usually without storage thus depends on seasonal flow.
Wind (onshore)	Most developed "new renewable" source; dominant in wind system; energy production depends on site and wind variability (annual, seasonal, synoptic, diurnal and turbulence); system can be grid-connected or stand-along system with storage (battery).
Wind (offshore)	With advantages on resources (with stronger, steadier and less turbulent wind), and environment (land use, noise effect and visual impact); the marine conditions are to be adapted (water depth, wave, seabed characteristics, distance to shore, ice formation, etc.); protection against corrosion; more costly than onshore mainly due to foundation (gravity based, piled, floating) and grid connection.
Solar photovoltaic	Storage necessary to meet no-sunlight case; PV modules, inverter and transformer as the other system components; can be stand alone or grid-connected; capacity of single PV module is small; idea for remote site without gird connection.
Solar thermal power	Similar to the fossil-fuel fired power system except for collector array; large scale and grid-connected; not economical when DNI level is below 1700 kWh/ (m2 · a); other site requirements include land area, land use, land slope, infrastructure, water resources; with technologies of parabolic trough, tower and dish.
Biomass power	Does not depend on weather conditions; relatively small scale (ca. 10–20 MW); desired for small application; power-heat plant available.
Geothermal power	System consists of thermal reservoir, power plant, wells and accessories; three kinds of system: vapor-dominated, flash and binary; injection well is extremely important to maintain supply of upflow.
Municipal solid waste (MSW); wave (shoreline, near-shore, offshore); tidal (stream, barrage), etc.	Can be included in other renewable powers, such as biomass and hydro.

change of pressure to avoid damage to the pressure pipe and other parts when the generator is switched to another mode.

Pumped-storage plant can reach an efficiency of 70– 90% and thus is economically attractive; on the other hand, it can help other fluctuating renewable powers, e.g. wind power, to integrate to the grid.

3.2. *Solar photovoltaic*

3.2.1. *General*

Basically there are two approaches to solar power generation. One is solar thermal power, which converts solar radiation to heat and then to electricity by thermodynamic power cycle; the other is photovoltaic process, a direct conversion to power.

The physics of photovoltaic (PV) cells is based on the same semiconductor principles as diodes and transistors. As long as sunlight exists, solar cells convert the energy to electricity. Solar cells do not store energy, so batteries are necessary for the PV system in order to meet the requirements in the evening or during cloudy conditions [18].

Electric voltage of single solar cell is just 0.6–0.7 V, thus many cells are interconnected in series to assemble solar modules to satisfy the need of practical applications. Furthermore, PV modules represent only the basic element of a solar power system, and they must work in conjunction with complementary components, such as batteries, inverters, and transformers.

Despite its environment-friendly characteristics, economically photovoltaic power may be just ideal for special applications, e.g. where a conventional electrical grid is unavailable, or where uninterruptible or emergency standby power is necessary.

3.2.2. *Stand-alone and grid-connected PV systems*

Currently PV power is extensively used in stand-alone power systems in remote areas. In the near future the potentially large application comes from the grid-connected PV systems which may more likely resist the barrier of expensive price, since the owner can sell the surplus electricity to the grid company. This really makes sense under the current background of excess production capability worldwide, especially in China.

Compared with the stand-alone system, PV systems fed into a public grid are built in a different way. First of all, more modules are needed; also a larger surface area is needed to install the system.

An inverter is also needed to convert the direct voltage from PV module to alternating voltage required by public grid. The inverter is multifunctional—it monitors the grid constantly and switches off the solar feed in case of power outage; it also ensures that the PV modules work with optimal voltage and deliver the maximum power [17].

Solar power can be used directly in the building where the system is installed. With power sourced from the sun, output of PV systems is inevitably unsteady. Thus the grid company acts as backup to provide the outstanding electricity in case of power shortage and accept the surplus electricity in the opposite case. However, electricity cannot be stored by the grid, thus the delivery of existing power plants must be adjusted. This will be an extra work for the grid company, and the government must coordinate with both sides and work out relative policies and regulations.

3.3. *Solar thermal power*

3.3.1. *General*

Majority of the existing thermal power plant are based on the Rankine cycle, which consists of two isentropic and two constant pressure processes. This cycle is also applicable to solar thermal power conversion. All components a solar thermal power plant needs are the same as those in a traditional thermal electricity generating station except the boiler. The "boiler" in a solar thermal power plant includes a solar collector field, a storage system, heat exchangers and an auxiliary fuel heater, which works whenever the solar system itself cannot meet the required temperature for the turbine. The maximum operating temperature of the system depends on what type the solar collector is. There are three kinds of such collectors—parabolic trough, tower and parabolic dish. The most popular technology is parabolic trough, and it has been demonstrated to be reliable by the serial SEGS plants in the Californian desert since 1985. Also parabolic trough solar power is the most pursued technology in China,

where several commercial projects are under planning or construction at the moment.

3.3.2. Parabolic trough concentrator

The key component of the plant, the parabolic trough concentrator (PTC), is the most commercially available solar concentrator, and it keeps the incoming radiation focused with the so called single-axis tracking, which is driven by a motor controlled by a programming computer. The collectors are assembled into large arrays, and normally the single-axis arrays can be arranged in two orientations: east–west (E/W) and north–south (N/S). Different arrangement will change the beam aperture irradiance and finally the received heat. Taken over the entire year, the N/S-oriented single-axis-tracking aperture receives slightly more energy than does the E/W axis aperture. However, the variation of the daily irradiance over the whole year is much greater for the N/S axis orientation than for the E/W orientation. As a result, if the energy demands for the system design are higher in the summer than in the winter (e.g. cooling demands), then the N/S orientation may be an advantage; in case of contrast demand, however, the E/W orientation is usually chosen [19].

It is critical to calculate the energy absorbed by the absorber of PTC collector, and the following expression is used [20]:

$$\dot{q}_A = IDR \bullet \eta_{opt} \tag{1}$$

where η_{opt} is the optical efficiency, the ratio of the solar radiation reaching absorber to that intercepted by the collector aperture. The efficiency is affected by the major collector optical factors, such as mirror reflectance, absorber and receiver cover transmittance, absorber absorptance, mirror surface slope error, mirror tracking error, etc.; IDR stands for Incident Direct Radiation, which is the available radiation on the aperture. IDR is determined by the DNI (Direct Normal Insolation) and the combination of cosine effect, incident angle modifier, shading loss and end loss.

3.4. Wind power

3.4.1. General

Use of wind as an energy source began in ancient times in power grain grinding, water pumping and sailing, and it has grown greatly as an important alternative for traditional electricity origins in the past years.

Basically wind power arises from the kinetic energy of air moving over the earth's surface. Wind turbine uses its blades to receive this kinetic energy and transforms it to mechanical and electrical forms.

Compared with traditional coal and gas-fired power plants, wind systems release no direct emissions (sulfur, nitrogen dioxides and carbon dioxide, etc.) and thus are generally regarded as environment friendly. However, the potential negative impacts, such as visual impact of wind turbine, wind turbine noise, land use impact of wind power systems, etc., should be kept in mind.

There are a number of land-related issues to be considered when siting wind turbines, among which land use is the one most standing out. On the area of occupied land per unit power capacity, wind farms require more than most of the energy technologies. Typical European wind farms need 13–20 ha per megawatt of installed capacity [21].

Lack of available land, together with abundance of wind resources and proximity to the electricity load center, has become the primary impetus of the booming development of offshore wind power in recent years. Wind energy is considered as the technique of dynamic development in the future, and this technology has been underlined in the proposal for the 12th Five-Year Plan [22].

3.4.2. Offshore wind power

Due to the rigid conditions, there are much more considerations for the offshore wind power compared with the onshore wind energy, regarding the wind turbines themselves, wind park siting, design and layout, operation and maintenance, environmental effects, etc., and the issue of electricity transmission can never be ignored.

Generation from the offshore wind power plant needs to be transferred underwater, thus attention should be paid to many technical and economical topics, such as transmission voltages, electricity losses, cable electrical characteristics and costs, cable burial technologies, etc.

Improper transmission can lead to significant energy losses and extra operation costs, thus the system designer needs to carefully make a choice between AC connection and DC connection.

Medium voltage is already enough if the distance to the shore is short. However, for long-distance transmission a high voltage transmission is needed. When comparing AC to DC transmissions, the AC terminal cost is less, while the line cost per cable length is less for the DC connection. Consequently AC connection will be economical for shorter distances, while the installation of DC lines is preferable above a certain distance. Also the transmission losses of HVDC would be lower than a comparable three-phase AC system. It should be noted that there are still other factors involved, such as the water depth, ground properties to assess investment cost, cable temperature rise, etc. [21,23].

3.5. Other renewable powers

3.5.1. Biomass

Biomass has been the oldest renewable energy source since the Stone Age. Driven by pressures from the sides of energy reserve and environment protection, it began to become popular once again worldwide. Besides the traditional functions like cooking & heating by wood firing, biomass is used to operate heating systems and power plants.

Power generation is a relatively new and important application of biomass. The plant is similar to that of conventional ones except for the fuels used. In a typical utility, organic material such as wood residues and straws are burnt in the boiler furnace, where heat is transferred to the heat exchanger, and steam superheating can occur. Steam is produced and converted to electric power in a high-speed steam turbine generator. Various economizers and recuperators may be installed to improve the efficiency.

Compared with PV and wind systems, output of biomass plant does not depend on the fickle weather conditions, so it is a reliable supplement to other renewable energy plants.

In contrast to the fossil-fired power plants with large capacities, biomass-fired plants usually have outputs in the range of 10–20 MW because of the restrictions of fuel availability, fuel cost consideration, and material handling difficulties associated with low-density fuels. However, biomass plant's size is ideal for smaller projects, such as industrial buildings, houses and apartment blocks, and this kind of plant can be designed to generate both electricity and heat to cover more applications. [17,24].

3.5.2. Geothermal

Geothermal electricity stations are designed to utilize thermal energy beneath the crust. This kind of system follows almost the same physics principles as the coal-fired and natural gas-fired power plants except that it does not produce its own heat and thus already skips most of the messy processes of the cycle.

Table 3
Targets of renewable powers by 2015 and 2020 compared with actual capacity by 2010.

Renewable power sources (MW)	2010 target	2010 on grid	Annual growth 2005–2010 (%)	2015 target	2020 target	Standard coal equivalent (t)
Hydro (conventional)	190,000	216,060	13.0	260,000	350,000	398.2×10^6
(Pumped-storage)				30,000	70,000	79.6×10^6
Wind	10,000	31,000	89.7	100,000	200,000	227.5×10^6
Solar PV	300	800	62.8	21,000	47,000	53.5×10^6
Solar thermal	0		0	1,000	3000	3.4×10^6
Biomass	5500	5500	22.4	13,000	30,000	34.1×10^6
Geothermal	None	24		100	None	
Total	205,800	253,384	14.4	425,100	670,000	796.3×10^6

A complete geothermal system consists of the thermal reservoir, the power plant, wells connecting the two, and accessories like pipes and valves. There are three methods of converting geothermal energy to electricity: the first and the simplest is the so-called vapor-dominated system—however, it is particularly difficult to find a qualified site. In such a system, steam from the production well is routed to the turbine through the piping and then to the condenser. Finally the liquid is injected back into the injection well to maintain the supply of the steam and also mitigate possible geological impacts.

The second is the so-called flash system which depends on hot water reservoir, the temperature of which is high and sometimes even exceeding twice the boiling point of water at atmospheric pressure (the water remains in liquid state due to the very high pressure within the earth). Working medium reaching the wellhead becomes a mixture of hot liquid water and high-pressure steam. The steam is directed to the turbine, while liquid water is pumped into the injection well. It is beneficial to maximize the steam production, thus a component named flash tank is added between the production well and the turbine.

The third method, so called binary system, is used at sites with not-so-hot water (but still higher than the boiling point of water at atmospheric pressure) from the earth. A binary system contains two loops with different fluids circulating inside, and the fluid in the first loop is hot water from the well. Hot water flows up to a heat exchanger, where the thermal energy from the water is transferred to the working fluid (e.g., isopentan) in the second loop, for later use in producing vapor to drive the turbine.

4. Targets and challenges for renewable powers in China

The Chinese government has pledged to cut its carbon dioxide emissions, with definite targets until 2015 (17% per unit GDP) and 2020 (40–45% per unit GDP). Due to the predominant influence of the power sector, China's electricity structure must be greatly improved and the proportion of the renewable powers needs to be increased apparently.

In order to boost renewable energy, China has amended the 2006 Renewable Energy Law, and the updated revision was formally put into force on April 1, 2010.

Compared with the old version which was promulgated in January 2006, the new Renewable Energy Law authorizes the National Energy Administration (NEA), to work together with Ministry of Finance and State Grid, to "determine the proportion of renewable energy power generation to the overall generating capacity during a certain period".

In the framework of the 12th Economical and Social Development Program, NEA has released the 12th Five-Year Development Plan for Renewable Energy on August 6, 2012, which specifies the targets for various renewable energies in the period of 2010–2015 and also until 2020 (Table 3).

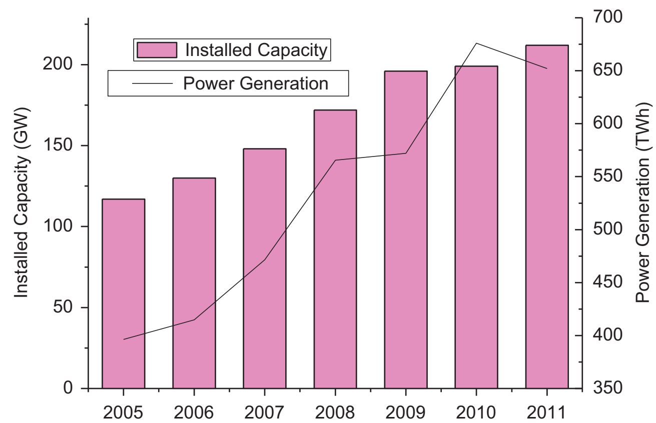

Fig.2. China's hydro capacity and power generation since 2005 (*Source*: China NEA).

At the end of the next Five-Year, electricity generation from renewable energy sources will become an important part of the overall power system—newly installed renewable energy capacity will reach 171.7 GW, including 74 GW of hydropower (pumped hydro counted), 69 GW of wind power, 21.2 GW of solar power (solar thermal counted) and 7.5 GW of biomass power. The renewable electricity generation would account for more than 20% of the overall electricity matrix.

However, there are still many challenges China needs to face, such as surplus manufacturing capabilities, insufficient grid connection, long distance between resources and consumers, etc., and all these must be thoroughly studied and carefully handled to ensure smooth development in the future.

4.1. Goals and challenges for hydropower

Due to its mature technology and economical cost, hydropower had seen a significant promotion in China during the last Five Year Plan (FYP)—generation capacity of 82 GW had been installed, with a growth average of 11.2%; in 2011, the installed capacity continued to increase by 6.5%. Besides the capacity, the electricity generation has also maintained a high growth except in 2011 (due to the much lower precipitation throughout the country) (Fig. 2).

To fulfill the commitments of cutting carbon emissions, hydropower will no doubt continue to play an important role in the future: at the end of the 12^{th} FYP (2011–2015), the installed capacity will reach 290 GW (with 30 pumped storage)—68.1% of various renewable powers in total; another 5 years later, the accumulated capacity will reach 420 GW—still 62.7% in total renewable electricity construction [25].

Rapid development of hydropower in China has resulted in impacts to the environment as well as burdens to the resource. Hydropower has always been controversial due to its destruction

of the habitats of fishes and plants, flooding of the homeland of indigenous people, releasing of climate-damaging methane, and the danger of dam breach. The famous Three Gorges Dam, which generates 84.7 TWh of power annually and reduces CO_2 emission by more than 70 million tonnes, has sacrificed housings of more than one million people and caused many ecological negatives, such as blocking of sewage and industrial wastes.

Resource is another bottleneck for development of hydro-power. The distribution of Chinese hydro-resources is uneven. Most of the hydro-resource is located in the west, especially Tibet, which owns 20.3% of the country's total technically exploitable capacity. However, as the "roof of the world", Tibet's high elevation and rigid natural conditions restrict its hydropower, and the installed capacity just accounts for 5% of the all the technically exploitable hydro-resource, the lowest among all the provinces, while in the middle and the east regions, the ratio is already 27.07% and 67.93%, respectively. The economic development gap between the west and the other regions (which determines electricity consumption) makes the contradiction more serious.

In the next FYP, the emphasis of Chinese hydro-power is in the vulnerable west. The government needs to balance the benefits and the disadvantages of the plants, to construct an ecologically sound equation.

4.2. Goals and challenges for solar PV and solar thermal

During the 11th FYP, China's installed solar PV capacity had been increased 62.3% annually in average; the electricity output had also grown at an average rate of 24.6%. In the period of 12th FYP, the high-speed growth will remain, and the until-2015 target for installed PV capacity was set to 21 GW, which means an annual increase of 87.9%. It seems that the amazing growth could be no doubt reached, since the actual capacity installed in 2011 has been 148.8% more than that in the previous year (Fig. 3).

However, huge challenges have appeared together with the opportunities. Chinese solar PV has always been "both ends facing outwards", whose supply of raw materials and sales of products highly depend on world market. Although there has been an apparent progress since the last FYP (Fig. 3), the domestic market scale is still much smaller (2.2 GW installed in 2011) compared with some European countries such as Germany and Italy (7.5 GW and 6.9 GW installed in 2011, respectively).

Benefiting from cheap labor force and tolerance to environmental pollution, but most importantly the government's support, China's PV manufacturing capacity has expanded to an astonishing magnitude—in 2011 Chinese PV module enterprises accounted for 74% of the global production output (29.5 GW) [26].

So vast oversupply has caused rapidly falling prices and trade wars with the US and Europe, and Chinese manufacturers have been put under huge pressure. The government has to take actions to safeguard its solar PV manufacturers. The former national long-term target (until 2020) of 20 GW for PV installation has been more than doubled to 47 GW (Table 3); several important policies have been issued to support this goal—China has launched feed-in tariff for on-grid solar PV electricity (USD 0.18/ kWh for stations built before Sep 2011, USD 0.16/ kWh for those thereafter); and the State Grids Corp. has announced to provide free connection service for distributed solar PV systems less than 6 MW since November 1, 2012. With these strong favors the Chinese domestic market is expected to be boosted and the aggressive new target could be achieved.

Contrasting sharply with the overproduction of solar PV, concentrating solar power (CSP) is just at the very beginning of industrialization in China. Northern and western China's abundant solar resources along with the large area of waste land make it feasible to develop CSP [27]. However, due to immaturity of the technology, there is no commercialized plant yet; only two small demonstration tower systems (70 kW and 1 MW) were built, and the operation result is still not satisfactory.

Ambitious targets for CSP until 2015 and 2020 are set to 1000 MW and 3000 MW, respectively (Table 3). NDRC has approved four CSP projects with total installation capacities of 242.5 MW. Nevertheless, there is no real action except the 50 MW project located in Delhi, Qinghai Province; the formerly highlighted 50-MW parabolic trough plant, which is located in Ordos, Inner Mongolia, invited bids in January this year (with knock down price USD0.15/ KWh), but still has no actual progress.

Technology and costs are major obstacles for developing CSP in China, and strong supports (such as attractive feed-in-tariff) from the government are necessary in this very beginning.

4.3. Goals and challenges for wind power

As one of the most economical and advanced renewable energy sources, wind power is very pursued globally—over the last five years global market growth of the total installed capacity reaches an impressive average of 26.5%. China remains the largest market with 17.63 GW newly added capacity, 42.3% of the total worldwide [28].

During the last FYP (2006–2010), China's wind power had been increased at an average of 89.7%, and it remains at a high growth of 39.4% in 2011 (Fig. 4). According to the medium and long-term plans, grid-connected wind power capacities will reach 100 GW until 2015 and 300 GW until 2020 (Table 3), which mean average growth rates of 17.4% and 24.6%, respectively.

Driven by the booming domestic demands, the Chinese wind turbine industry has become considerable in the global market. Four Chinese turbine manufacturers were among the global top 10 at the end of 2011—with an annual installed capacity of 3.79 GW, Goldwind occupied the second place next to Vestas; the other members of the league include Sinovel (No. 7 with 2.94 GW), United Power (No. 8 with 2.86 GW) and Mingyang (No. 10 with 1.18 GW). This team (10.77 GW in total) already accounted for 25.8% of the global market in the last year [29].

According to the experiences during the last period, there is no doubt China will achieve its 12th FYP target for wind power. But several formidable challenges remain to the wind energy development in China, such as the mismatch between the grid and wind farm planning, grid curtailment, surplus production, and lack of offshore marine utilization plan, etc. The period of 12th FYP would be critical for the development of Chinese wind power.

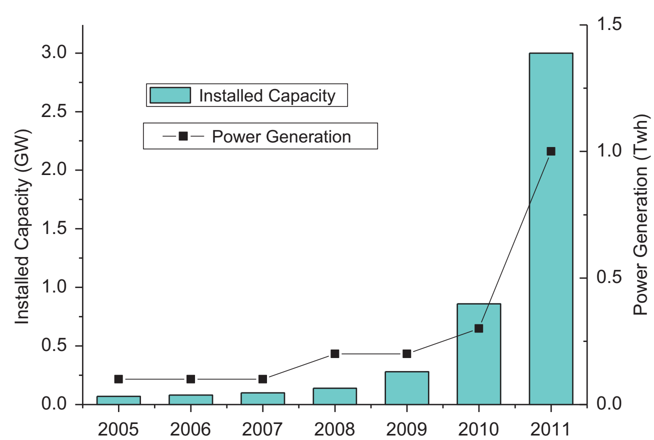

Fig.3. China's solar PV capacity and power generation since 2005 (*Source*: China NEA).

In 2011 grid curtailment has become the most outstanding problem—over 10 TWh electricity has to be lost [30]. Solving this issue is challenging—the grid system was designed for a coal dominated power system, thus there is lack of flexibility which makes it difficult to integrate more wind power in the system.

4.4. Goals and challenges for other renewable powers

Biomass power had been grown at an average rate of 22.4% during the 11th FYP period, and the target for 12th FYP was set to 13 GW, which means an annual growth of 18.8% (Table 3); it is specified in the long-term plan until 2020 that biomass power capacity would reach 30 GW, which means a growth rate of 18.2% for another five years (2016–2020).

Biomass power is strongly supported by the Chinese government, since it can not only utilize the large quantity of crop straws, but also increase the peasants' incomes and contribute to social stability.

Most of the existing biomass plants have difficulties to collect enough material to operate the facilities in full capacity, for they are too close to each other and lead to disorderly competition for the limited straws. Planning of biomass projects and siting of the plants need to be improved in the medium and long-terms.

Another challenge comes from the data library of biomass resources. Detailed investigations and evaluations are still lacking regarding the crop quantities, geographical distribution, collecting costs, cultivation potentials, etc.

Another renewable power, geothermal, only presents a tiny proportion in the whole structure. Yangbajain (24 MW) is currently the only functioning plant in China. There is no newly built geothermal electricity station during the 11th FYP, and several old plants were scrapped due to equipment aging or resource exhausting; the target for the 12th FYP is set as 100 MW, 4 times the current scale.

Risks restrict the development of geothermal electricity generation in China, for exploration needs a package of technologies including detecting, evaluating, extracting, reinjection, power generation and heat utilization. Thus well-arranged and progressive procedures are realistic for this still small renewable power.

5. Solutions from the source

According to the mid-term plan, the amount of various renewable powers will achieve standard coal equivalent of 796.3×10^6 t (Table 3), which equals CO_2 emission reduction of 1.99×10^9 t.

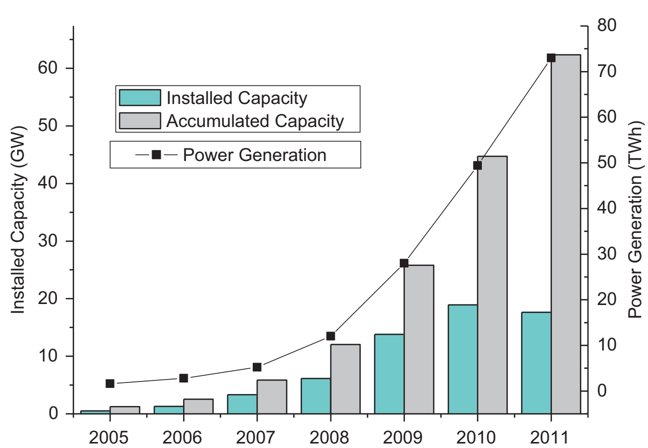

Fig.4. China's wind power capacity and power generation since 2005 (*Source*: China NEA).

On the other hand, the Chinese economy still maintains a high-speed growth. The central government has committed to quadruple the total GDP value until 2020 from the level of 2000, and therefore China's total carbon emission will inevitably continue to rapidly climb up until even the mid-term target of emission intensity per GDP unit could be achieved.

Unlike the developed countries and most other developing countries, the expansion of Chinese economy is seriously dependent upon intensive energy consumption. In 2011, China spent 21.3% of the total world electricity generation and primary energy (4700.1–22018.1 terawatt-hours and 2613.2–12274.6 million tonnes oil equivalent, respectively), plus 26.4% of the total world carbon dioxide emissions (8979.1–34032.7 million tonnes) to produce just 10.4% of the total world output (GDP, USD 7298.1 billion to USD 69899.2 billion at market exchange rates). This is certainly unsustainable [31].

It makes no sense to make great efforts to reduce carbon emissions if there is no significant saving in the power demand. The current path of economy development must be changed from the origin by the Chinese government.

6. Conclusions

To fulfill the commitments of greenhouse gas emission reduction to the world and change the unsustainable economic development mode, the Chinese government has emphasized the roles of renewable electricity in the 12th FYP and the long-term plan until 2020.

Among various renewable powers, hydro power will remain in the predominant position due to its mature technology and competitive cost, and pumped storage will be emphasized due to its advantages such as high efficiency and compensating grid fluctuation. However, a balance must be reached between the benefits and the environmental negatives.

Solar PV installation from 2011 to 2015 was planned to develop at an amazing growth of 87.9%. There is no doubt that this target could be reached from the angle of the Chinese production capacities, which accounted for 74% of the current global output. However, with shrinkage of the international purchasing, the future is determined by how much the domestic market can expand.

Compared with solar PV, solar thermal power is just at the very beginning of industrialization in China, but ambitious targets have been set until 2015 and 2020. Due to technology and cost obstacles, several CSP projects have been trapped in difficulties. Strong supports such as attractive feed-in-tariff are necessary at this difficult moment.

As the largest market owner of wind machine, this renewable power source will continue its high growth according to the medium and long-term plans, which are specified as 17.4% from 2011 to 2015 and 24.6% from 2016 to 2020, respectively. It seems that these targets can be easily reached according to the experiences in the past and in 2011. But severe challenges must be kept in mind and handled with strategies, such as grid curtailment, surplus production, and lack of offshore marine utilization plan, etc.

The Chinese government strongly encourages biomass, and has specified the targets of growth for the mid- and long-term plans as 18.8% and 18.2%, respectively. However, reasonable planning and siting of the projects, as well as establishing of a data library of the biomass resources, are the major subjects to be studied and resolved.

There is only one functioning geothermal power plant (24 MW, in Tibet). It looks as if the target of 100 MW specified in the 12th FYP would be difficult to reach. This still small

renewable power source is encountering a bottleneck in China, thus well-arranged and progressive measures are realistic to minimize the risks for the exploration.

The above mentioned renewable powers can contribute greatly to carbon dioxide emission reduction in China, but the solution from the source is to make significant saving from the side of energy demand. The actions against climate change can never be successful without real transition of the current costly economy development mode.

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